Final Report

FHWA/IN/JTRP-2006/24

Determination of Ash Mixture Properties and Construction of Test Embankment - Part B

by

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Joint Transportation Research Program
Project No. C-36-36HH
File No. 6-14-37
SPR-2591

Conducted in Cooperation with the
Indiana Department of Transportation
and the U.S. Department of Transportation
Federal Highway Administration

Purdue University
West Lafayette, Indiana
November 2006

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/IN/JTRP-2006/24		

4. Title and Subtitle	5. Report Date
Determination of Ash Mixture Properties and Construction of Test Embankment - Part B	November 2006
	6. Performing Organization Code
7. Author(s) Sungmin Yoon, Umashankar Balunaini, Monica Prezzi, Rodrigo Salgado, and Nayyar Zia Siddiki	8. Performing Organization Report No. FHWA/IN/JTRP-2006/24
9. Performing Organization Name and Address Joint Transportation Research Program 550 Stadium Mall Drive Purdue University West Lafayette, IN 47907-2051	10. Work Unit No.
	11. Contract or Grant No. SPR-2591
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204	13. Type of Report and Period Covered Final Report
	14. Sponsoring Agency Code

15. Supplementary Notes

Prepared in cooperation with the Indiana Department of Transportation.

16. Abstract

According to the American Coal Ash Association, 70 and 18 million metric tons of fly and bottom ash were produced in 2003, respectively. Only 38 % of the total production was recycled. Due to increasing disposal costs, reduction of landfill space and need for conservation of natural resources, it is essential to find beneficial ways of reusing fly and bottom ash in secondary applications. About 15 % of the fly ash recycles as a fill material in civil engineering applications. The engineering properties of fly- and bottom-ash make it a viable fill material, compared to other conventional structural fill materials

This research presents the construction of a demonstration embankment using a fly- and bottom-ash mixture as fill material. The highway embankment was designed and constructed by the Indiana Department of Transportation in 2005. This demonstration project is located at State Road 641, Terre Haute, IN.

The results of laboratory tests, which were performed to characterize the properties of the ash mixture, and the field data obtained from quality control tests performed during construction of the demonstration embankment are presented. The instrumentation of the embankment consists of settlement plates, settlement cells, vertical and horizontal inclinometers, and earth pressure cells. The performance of the embankment was evaluated based on field performance.

17. Key Words	18. Distribution Statement
Recycling, waste materials, fly ash, bottom ash, embankment, monitoring	No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	41	

Form DOT F 1700.7 (8-69)

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ACKNOWLEDGEMENTS

This work was supported by the Joint Transportation Research Program administered by the Indiana Department of Transportation and Purdue University, Cinergy/PSI, Vectren Corporation, and the Indiana Department of Commerce. The contents of this paper reflect the views of the writers, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or polices of the Federal Highway Administration and the Indiana Department of Transportation, nor do the contents constitute a standard, specification, or regulation. The authors are thankful to Howard Lewis for his support during this project. The authors appreciate the help of John Carpenter and Nelson Brown of INDOT in field monitoring work.

IMPLEMENTATION REPORT

According to the American Coal Ash Association, 70 and 18 million metric tons of fly and bottom ash were produced in 2003, respectively. Only 38 % of the total production was recycled. Due to increasing disposal costs, reduction of landfill space and need for conservation of natural resources, it is essential to find beneficial ways of reusing fly and bottom ash in secondary applications.

About 15% of the fly ash recycled in the US is used as a fill material in civil engineering applications. Fly ash exhibits relatively superior engineering properties than conventional structural fill materials. Fly ash and fly- and bottom-ash mixtures exhibit relatively high friction angle (ϕ_p ranges from 30^o to 40^o) and relatively low dry unit weight (ranging from 14.1 kN/m^3 to 17.7 kN/m^3). In addition, the hydraulic conductivity of fly ash and fly- and bottom-ash mixtures is similar to that of a fine sandy silt or silt (2×10^{-8} to 1×10^{-7} m/s). Fly ash has been utilized successfully as a fill material in several demonstration projects in the US. However, there is limited information in the literature on the performance of highway embankments constructed with fly- and bottom-ash mixtures.

This research presents the construction of a demonstration embankment using a fly- and bottom-ash mixture as fill material. The highway embankment was designed and constructed by the Indiana Department of Transportation (INDOT) in 2005. The results of laboratory tests, which were performed to characterize the properties of the ash mixture, and the field data obtained from quality control tests performed during construction of the demonstration embankment are presented. The following summarizes the work done and the results of the laboratory testing and field instrumentation program:

(1) A high-volume test embankment using an ash mixture was constructed at State Rd. 641, in Terre Haute, IN. The fill material consists of a mixture of Class F-fly ash and bottom ash (60:40 by mass). The ash mixture was classified as sandy silt according to the USCS. The height, length and width of the test embankment are equal to 7.6 m, 60 m and 100 m, respectively.

(2) The maximum dry unit weight and the optimum moisture content of the ash mixture were found to be equal to 15.1 kN/m^3 and 19 %. It is lighter than the typical fill materials used in highway construction. For this reason, use of ash in embankment construction reduces problems associated with settlement and instability of embankments constructed on top of soft soil deposits. In addition, transportation costs are also reduced because of the reduction in truck load.

(3) Compaction procedures were determined based on test pad results. Nuclear gauge, microwave-oven, and DCPT tests were used for compaction quality control. Based on the test pad results, it was concluded that a DCPT blow count of more than 6 per 150-mm penetration was needed to achieve 95 % of the laboratory $\gamma_{d,max}$.

(4) An empirical correlation between the DCPT blow count and $\gamma_{d,max}$ was proposed based on the data available.

(5) The ash mixture was found to be very uniform. This was quite helpful in achieving uniform compaction of the mixture during construction of the embankment as well. The compaction control was carried out at relatively fewer locations due to the observed fill uniformity. In fact, quality control was relatively easy to accomplish in this project.

(6) The pore pressure developed in each construction stage was maintained below the critical pore pressure measured by the piezometers.

(7) A maximum settlement of 80 mm was observed at the bottom of the embankment; the settlement stabilized approximately three months after the end of construction of the embankment.

(8) Differential settlement of about 5 mm was observed at the top of the ash embankment according to horizontal inclinometer readings obtained approximately after five months of monitoring.

(9) Negligible lateral movements were observed at the shoulder and toe of the embankment; these observations were confirmed by vertical inclinometer readings.

(10) The laboratory and field test results show that the fly- and bottom-ash mixture used in the construction of the demonstration embankment is a viable alternative to conventional fill materials, as it is lightweight and has high strength.

CHAPTER 1. INTRODUCTION

According to the American Coal Ash Association (2005), 70 and 18 million metric tons of fly and bottom ash were produced in 2003, respectively. Only 38 % of the total production was recycled. Due to increasing disposal costs, reduction of landfill space and need for conservation of natural resources, it is essential to find beneficial ways of reusing fly and bottom ash in secondary applications.

Out of the total amount of fly ash recycled, about 61% has been used in concrete, as fly ash can improve the properties of concrete through pozzolanic reactions. About 15% of the fly ash recycled is used as a fill material in civil engineering applications (American Coal Ash Association 2003). Research performed on the engineering properties of fly ash revealed that, compared with conventional structural fill materials, fly ash and fly- and bottom-ash mixtures exhibit relatively high friction angle (ϕ_p ranges from 30^o to 40^o) and relatively low dry unit weight (ranging from 14.1 kN/m^3 to 17.7 kN/m^3) (Kim et al. 2005). In addition, the hydraulic conductivity of fly ash and fly- and bottom-ash mixtures is similar to that of a fine sandy silt or silt (2×10^{-8} to 1×10^{-7} m/s). These engineering properties make the use of fly- and bottom-ash mixtures suitable as fill materials for embankments and retaining structures (Kim 2003). Fly ash has been utilized successfully as a fill material in several demonstration projects (Rehage and Schrab 1995; Alleman et al. 1996). However, there is limited information in the literature on the performance of highway embankments constructed with fly- and bottom-ash mixtures.

This report presents the construction of a demonstration embankment using a fly- and bottom-ash mixture in the mixing ratio of 60/40 (fly ash/bottom ash) as fill material. The ashes are deposited together in a disposal pond and extracted using a backhoe. The highway embankment was designed and constructed by the Indiana Department of Transportation (INDOT) in 2005. This demonstration project is located at State Road 641, Terre Haute, IN. The ash used in this project is produced by the Wabash River plant located in West Terre Haute, IN (Figure 1). Figure 2 shows an overview of the embankment location.

The results of laboratory tests, which were performed to characterize the properties of the ash mixture, and the field data obtained from quality control tests performed during construction of the demonstration embankment are presented. The instrumentation of the embankment consists of settlement plates, and vertical and horizontal inclinometers. Results obtained from monitoring of the settlement plates throughout the construction of the embankment are presented. The performance of the embankment was monitored for over one year after the start of construction.

Figure 1 Location of the ash demonstration embankment in the state of Indiana.

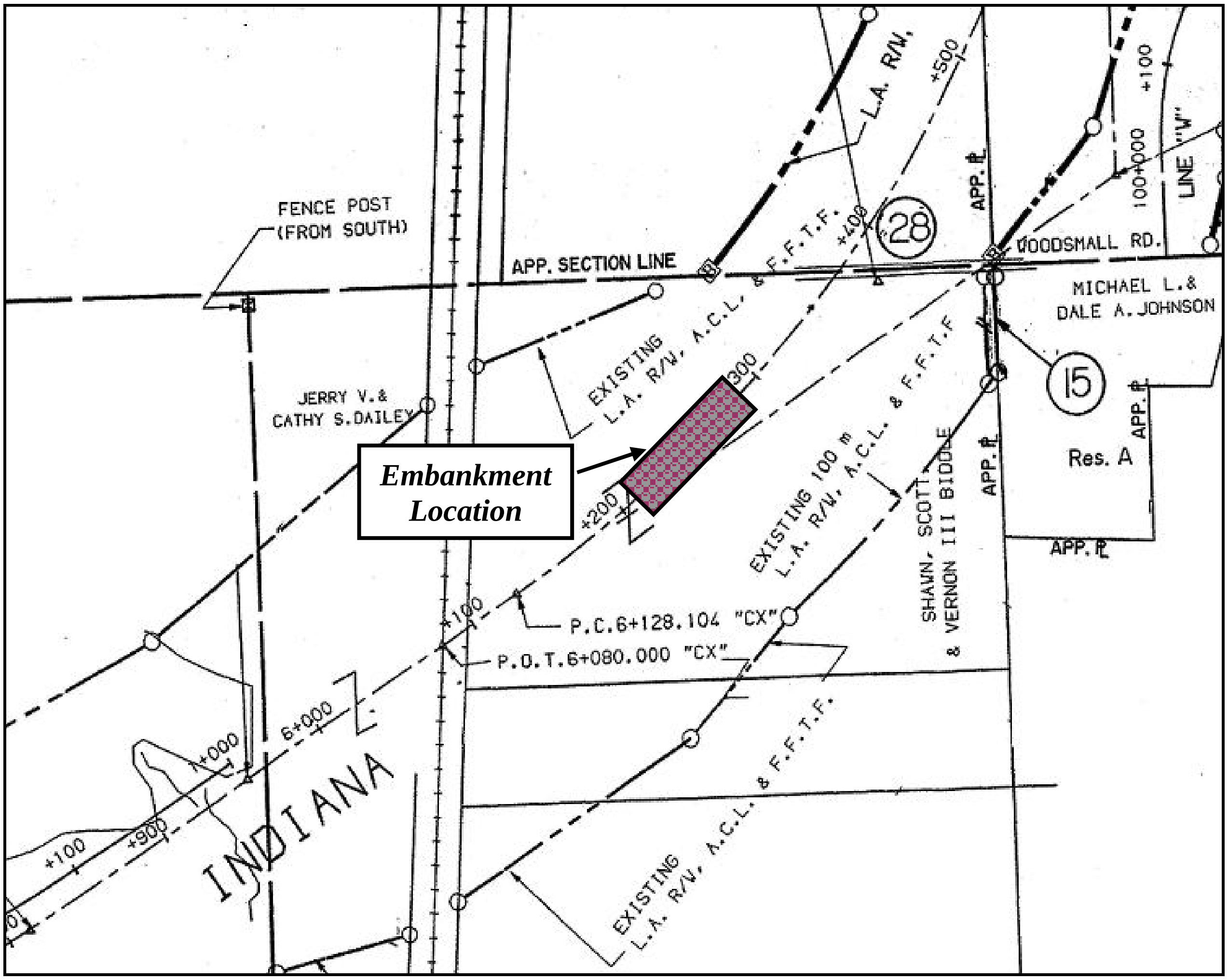

Figure 2 Overview of embankment location on site map.

CHAPTER 2. PROPERTIES OF FLY- AND BOTTOM-ASH MIXTURE

2.1. Specific Gravity

The specific gravity G_s of fly ash and bottom ash varies with the chemical composition of the coal used in power plants. Higher iron contents in the ash may result in higher specific gravity values (Kim 2003). Typical values of G_s range from 2.1 to 2.9 for Class-F fly ash (McLaren and DiGioia 1987) and, from 2.0 to 2.6 for bottom ash (Seals et al. 1972; Moulton 1973; Anderson et al. 1976; Majidzadeh et al. 1977). The specific gravity of the fly- and bottom-ash mixture used for the construction of the demonstration embankment, as determined by method A (ASTM D 854-00), is equal to 2.5.

2.2. Compaction Characteristics

Standard compaction tests were performed on the fly- and bottom-ash mixture in accordance with ASTM D698 to determine the maximum dry unit weight $\gamma_{d,max}$. As shown in Figure 3, $\gamma_{d,max}$ is 15 kN/m^3, and the optimum moisture content w_{opt} is 19 %. The zero-air-voids line is also shown in Figure 3.

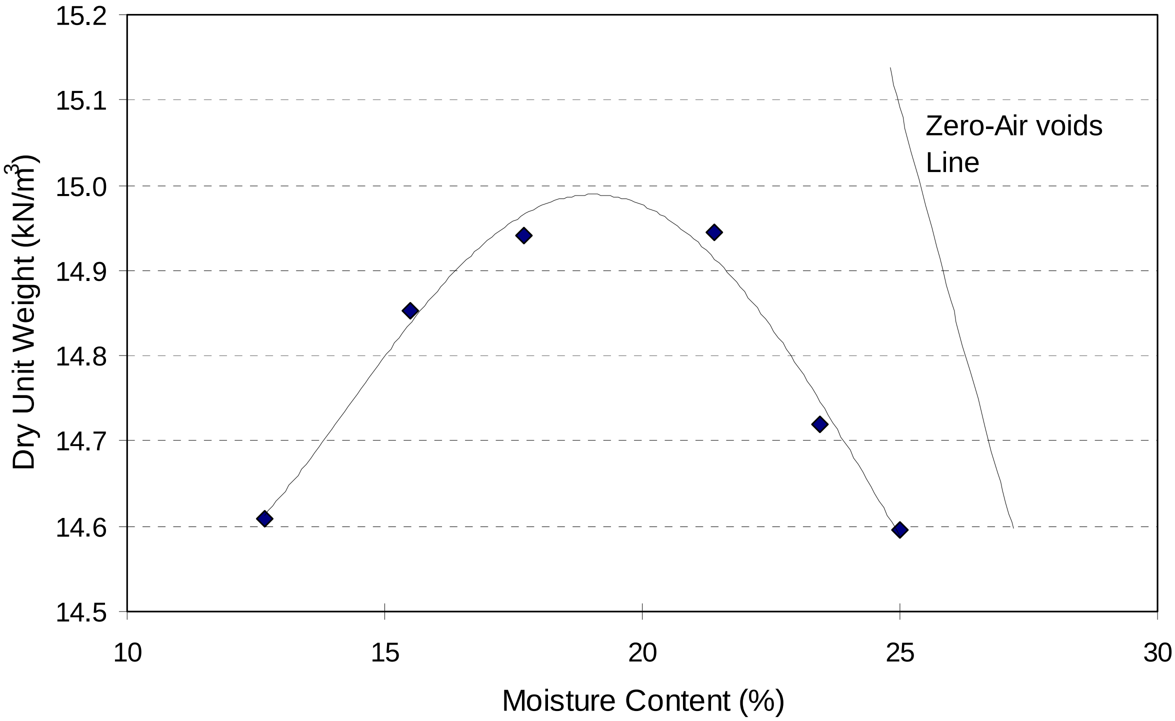

Figure 3 Compaction curve for the fly- and bottom-ash mixture.

2.3. Grain Size Distribution

Grain size analysis was performed on fly- and bottom-ash samples collected from the construction site. Figure 4 shows that 60 % of the mixture, by weight, passed the No. 200 sieve (0.075 mm). The fly- and bottom-ash mixture used in the project is classified as sandy silt (ML) according to the Unified Soil Classification System (USCS). It exhibits non-plastic behavior, and more than 50 % of the particle sizes are in the silt size range (75 μm to 2 μm).

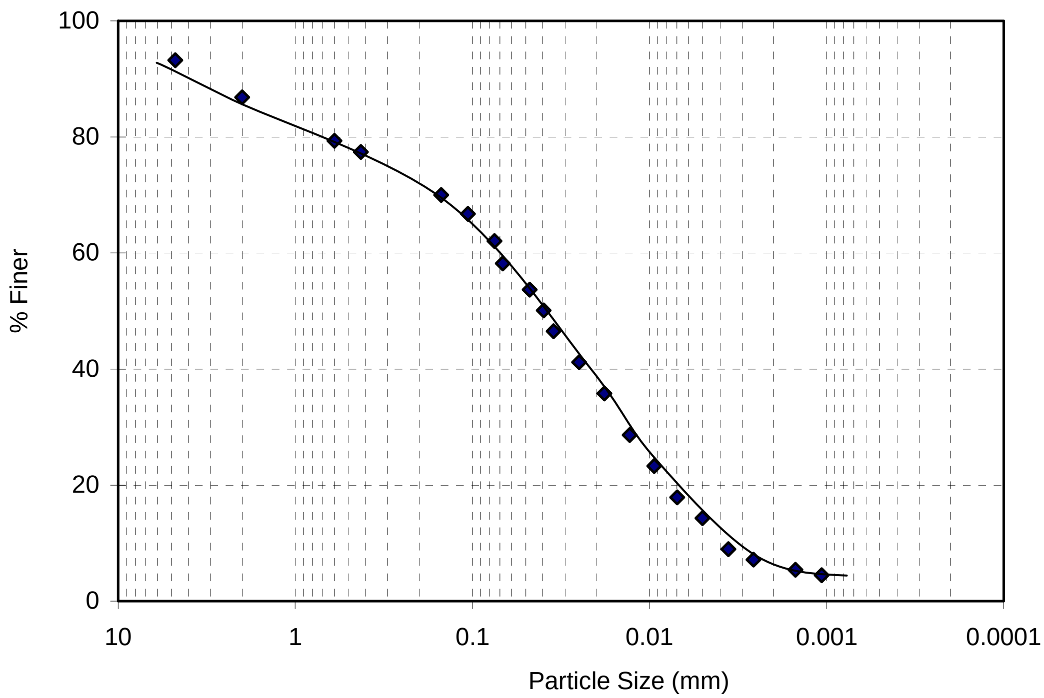

Figure 4 Grain size distribution of the fly- and bottom-ash mixture used in the construction of the demonstration embankment.

2.4. Chemical Composition

The chemical composition of ash depends on the characteristics and composition of the coal burned in power plants. Table 1 shows the oxide composition of the fly ash and bottom ash used in the construction of the demonstration embankment. The major constituents of these ashes are SiO_2, Al_2O_3, and Fe_2O_3. These three oxides combined constitute about 86 % and 70 % (by mass) of the fly ash and bottom ash, respectively.

Table 1 Chemical composition of fly and bottom ash produced by the Wabash River plant

Constituent	% by mass	
	Fly ash	Bottom ash
SiO_2	51.13	39.64
Al_2O_3	22.91	15.08
Fe_2O_3	12.18	15.02
TiO_2	1.01	0.70
CaO	1.54	2.04
MgO	0.73	0.79
K_2O	2.55	1.79
Na_2O	0.38	0.27
SO_3	0.07	0.21
P_2O_5	0.14	0.13
SrO	0.05	0.04
Mn_3O_4	0.04	0.03

CHAPTER 3. DESIGN AND CONSTRUCTION OF ASH EMBANKMENT

In order for the embankment to perform satisfactorily, the ash fill must satisfy two criteria: 1) it must have adequate strength to support safely its self weight and that of the traffic loads, and 2) it must be sufficiently stiff to prevent excessive settlement during the service life of the pavement. Slope stability and settlement analyses need to be performed to determine the best way to meet these requirements at the embankment design stage.

3.1. Design for Staged Construction

Embankments may become unstable due to excess pore pressure development in the foundation soil (see Appendix for the boring logs performed at the construction site). Because of the low hydraulic conductivity of the clay loam layer found at the embankment site location, generation of excessive pore pressure in this layer was a concern. Excess pore pressure values were calculated in the center of the clay loam layer during various stages of the embankment construction (embankment heights: 2.5 m, 5.00 m and 7.60 m). If we define the critical pore pressure as the pore pressure leading to a FS equal to 1.3, then, at every stage of construction, the pore pressure developed in the foundation soil must not exceed the calculated critical pore pressure. When the pore pressure generated in the foundation soil approaches the critical value, the construction must be stopped until the excess pore pressure dissipates.

3.2. Environmental Considerations

Leaching of trace metals from fly and bottom ash is the main environmental concern in embankment construction using these materials. Migration of metals from ash into groundwater has been studied in a number of high-volume ash projects (Srivastava and Collins 1989, Rehage and Schrab 1995, and Alleman et al. 1996). According to these studies, groundwater contamination due to coal ash usage was minimal.

3.3. Layout

The height, length and width of the test embankment are equal to 7.6 m, 60 m and 100 m, respectively. Figure 5 shows a plan view of the embankment with the location of the settlement plates, and horizontal and vertical inclinometers. Stations 6 + 220 and 6 + 280 bound the length of the ash embankment. Figure 6 shows cross-section of the embankment at location 6+250. Boring logs conducted at the center of the embankment (6 + 250) are shown in Appendix section (Figure A.1)

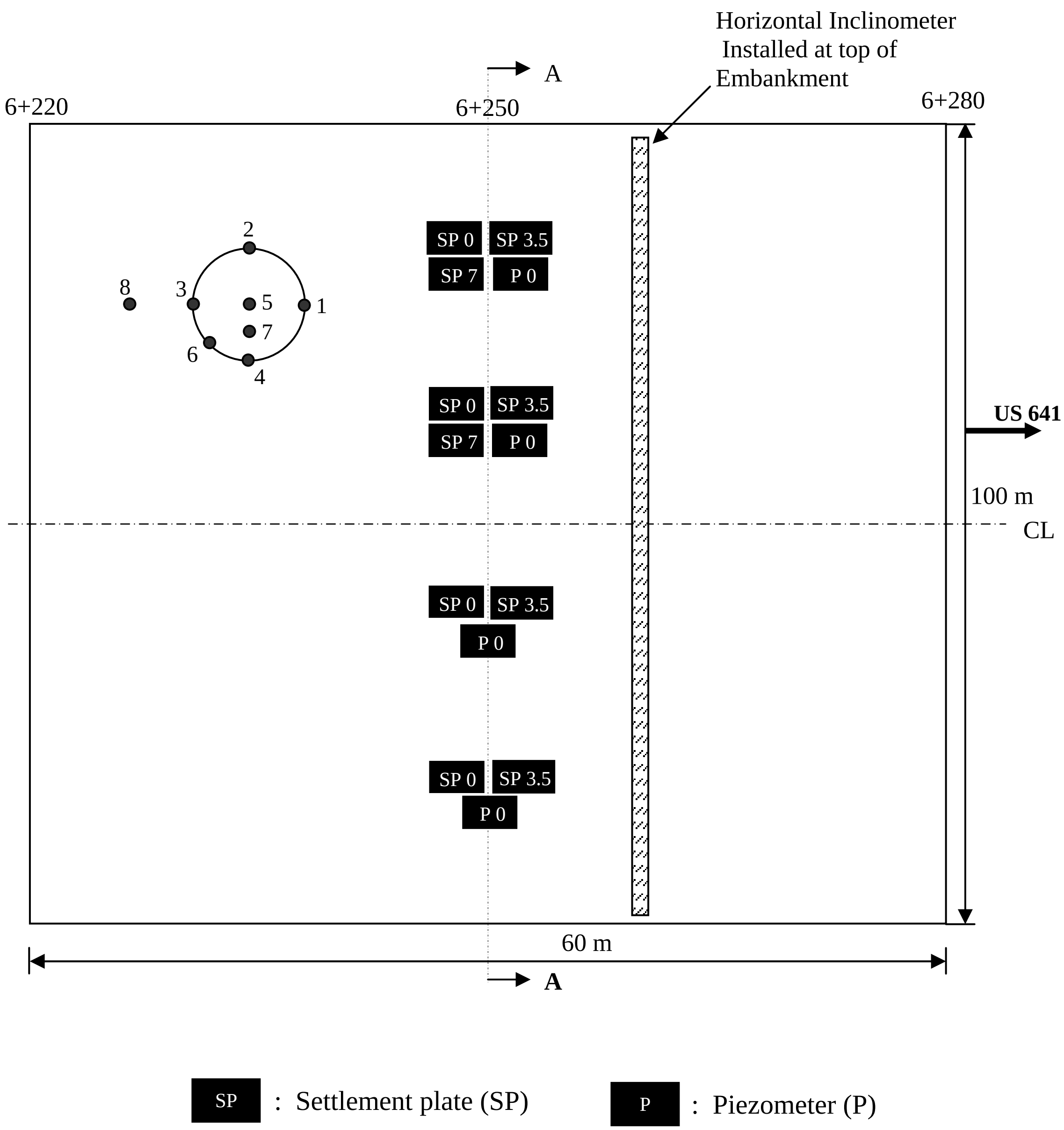

Figure 5 Location of the settlement plates and piezometers.

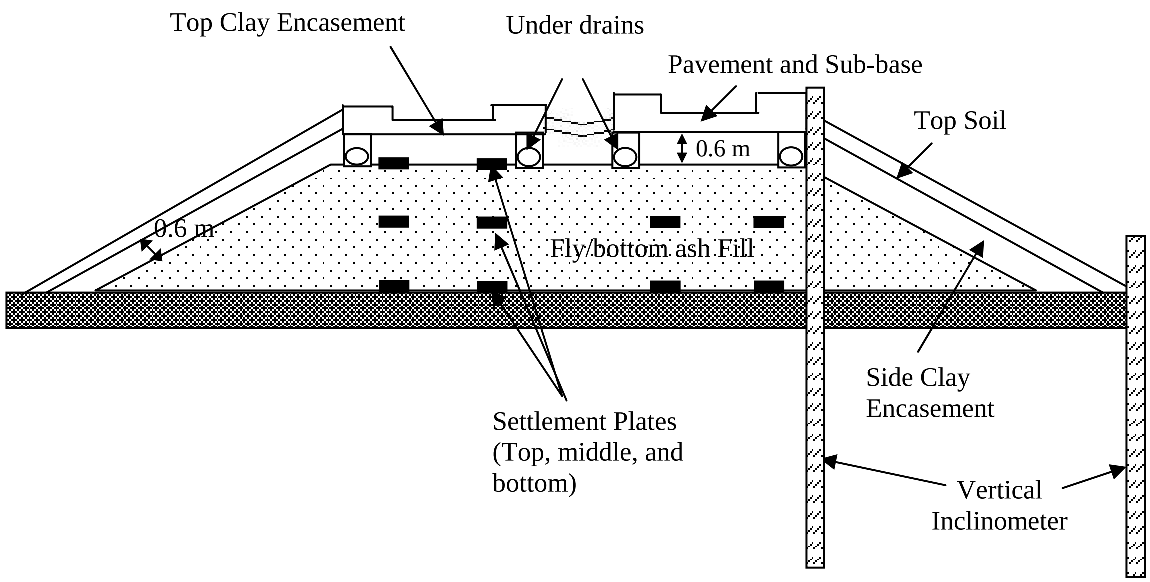

Figure 6 Schematic cross-section of the test embankment at station 6+250.

3.4. Test Pad Construction

Before starting the embankment construction, a test pad was constructed to establish the specifications for compaction quality control in the field. The nuclear gauge and the microwave-oven tests were chosen to determine the in-situ density and water content of the compacted ash. Based on the test pad results, the Dynamic Cone Penetration Test (DCPT) was selected for the embankment compaction quality control as well. The details of the nuclear gauge, microwave oven and DCPT tests are given next.

3.4.1. Nuclear Gauge Test

The total unit weight of the compacted ash was estimated using a nuclear gauge employing the standard 1-minute count and direct transmission mode (ASTM D2922). Calibration of the nuclear gauge was done according to the procedure proposed by Alleman et al. (1996). Eight nuclear gauge and sand cone tests were performed on the compacted ash pad at specified locations around a circle (see Figures 7 through 9). The highest and lowest values of the total unit weight from the nuclear gauge tests were discarded to account for any possible errors in the test. The remaining six values were used to calibrate the nuclear gauge test results using the sand cone test results.

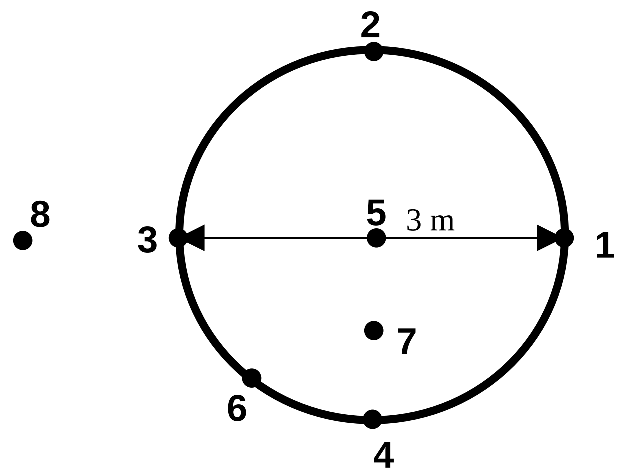

Figure 7 Schematic of stations identified for nuclear gauge, sand cone and microwave-oven tests

Figure 8 Stations marked at test pad.

Figure 9 Nuclear gauge testing at test stations.

3.4.2. Microwave-Oven Heating Method

The water content of the compacted ash was determined using the microwave-oven heating method (ASTM D 4643). In order not to overheat the sample, drying was done at 30 % of the full power of the microwave oven. Initially, the sample was dried in the microwave oven for 13 minutes and, subsequently, for 1-minute intervals. The drying process was continued until a change of 0.1 % or less of the initial wet mass was recorded.

3.4.3. Dynamic Cone Penetration Test

DCPT's were conducted in accordance with ASTM D 6951 at the same locations in the test pad as the nuclear gauge and microwave oven tests (see Figure 10). The DCPT results on the compacted ash indicated consistently that 5-7 blow counts are required to penetrate a thickness of one lift (150 mm). Based on these results, it was recommended that the DCPT blow count per 150-mm penetration of compacted ash should be more than 6 in order to achieve 95 % relative compaction.

Based on the evaluation of the test pad results, a 150-mm-lift thickness and three vibratory roller passes using a D-10 vibratory roller (CAT CS-563D with 266 kN centrifugal force) were recommended in order to achieve 95 % relative compaction (Figure 11).

Figure 10 DCPT at test stations.

Figure 11 Compaction equipment used.

3.5. Embankment Compaction

150-mm-thick lifts of the fly- and bottom-ash mixture were placed on top of the prepared subgrade. Each layer of ash was uniformly placed across the length of the roadway cross-section. A steel track bulldozer (CAT D7 50) was used to spread out the fill material and to provide additional compaction (Figure 12).

Figure 12 Steel track bulldozers used to spread fly ash.

3.6. Quality Control

Quality control (QC) of the compacted ash was done at 15-m intervals along the embankment length for every lift (150 mm). QC was done in two ways: a) using the nuclear gauge and microwave-oven heating tests to determine the in-situ density and in-situ water content of the ash mixture compacted in the embankment, and b) using DCPT.

Figure 13 illustrates the relationship between the DCPT blow count per 150-mm penetration and the in-situ dry unit weight of the compacted ash. The blow count increases as the dry density increases. An empirical correlation for the DCPT blow count (BC) derived in terms of the in-situ dry unit weight (for water contents in the range from 20.4 to 23.8 %) is as follows:

$$BC = 3\gamma_d - 40.5 \tag{1}$$

where *BC* is the blow count per 150-mm penetration and γ_d is the dry unit weight in kN/m^3.

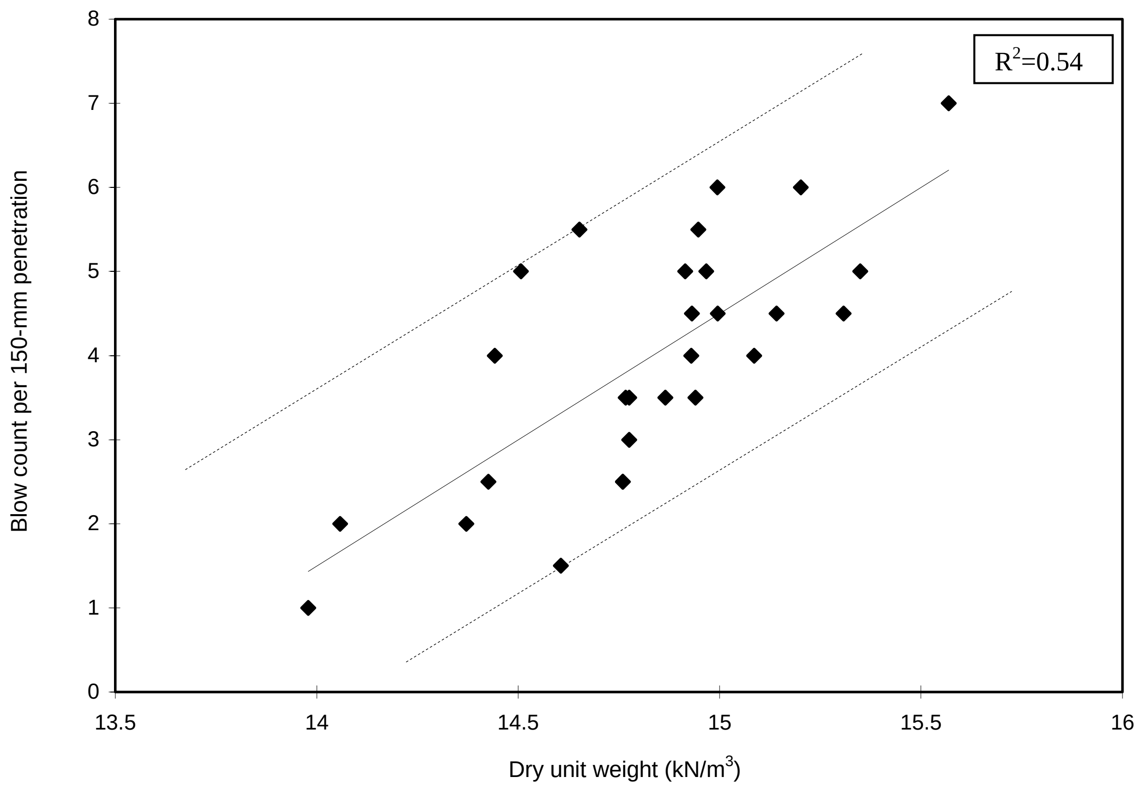

Figure 13 DCPT blow count versus field dry unit weight of the ash mixture.

CHAPTER 4. FIELD INSTRUMENTATION PROGRAM

4.1. Settlement Plates

Ten settlement plates were installed along the center line (CL) of the embankment (section 6+250). Settlement plates were installed at three depths (bottom, mid-height and top of the embankment). Eight settlement plates were installed at four different locations (7.8 m and 17.7 m from the CL along the southeast and northwest sides of the embankment), as shown in Figure 5, at the bottom and mid-height of the embankment. The remaining two plates were placed on top of the ash embankment. Figure 14 shows the installation of a typical settlement plate in the field. Field monitoring of the settlement plates was done for a period of one year since the beginning of embankment construction. The ash fill settled during construction as a result of the embankment self-weight. The settlement data obtained from the plates placed at the bottom and mid-height of the embankment at various locations along the 6+250 section are shown in Figure 15 through Figure 18. The settlement data obtained from the bottom plates at locations 7.8 m and 17.7m at the southeast side of the embankment are not shown for the entire one year period, as the settlement plates were damaged during construction.

The maximum settlement, which was more or less the same for the bottom plates, was equal to about 80 mm, and it stabilized about six months after the start of construction. The settlement at the mid-height of the embankment stabilized to a maximum value of about 70 mm about five months after the installation of the plates. A total settlement of 20 mm was recorded at the top of the ash embankment approximately four months after the start of installation of the settlement plates.

Figure 14 Installation of settlement plates.

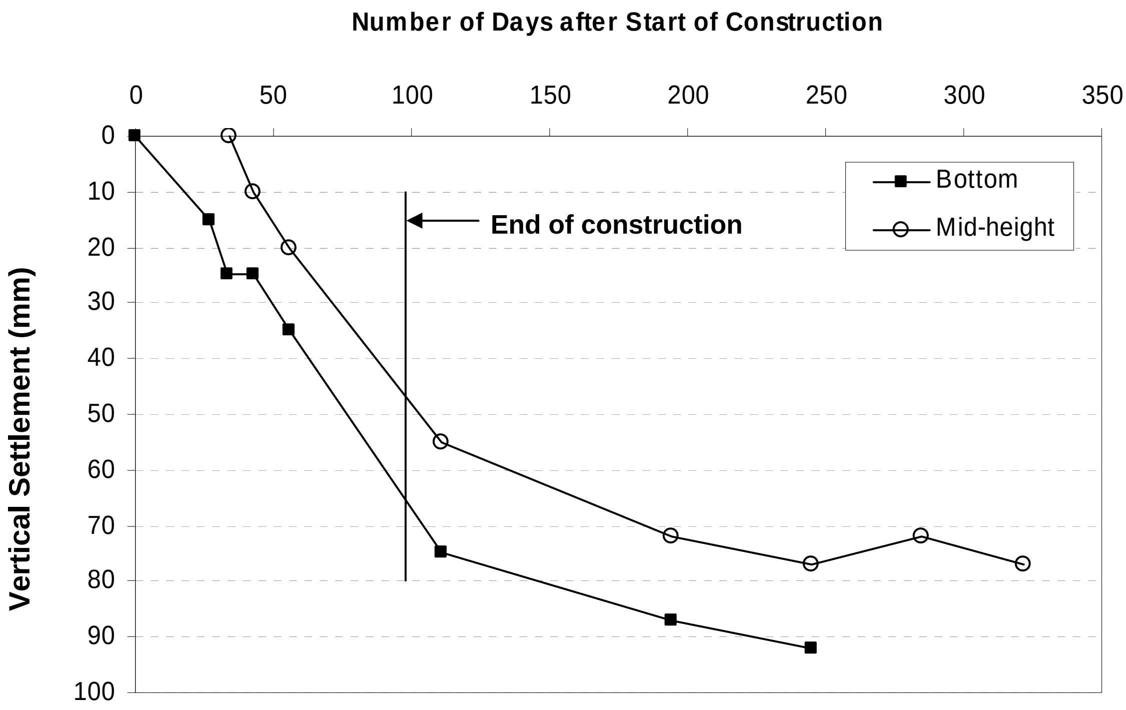

Figure 15 Settlement versus number of days after start of construction (7.8m-Northwest side).

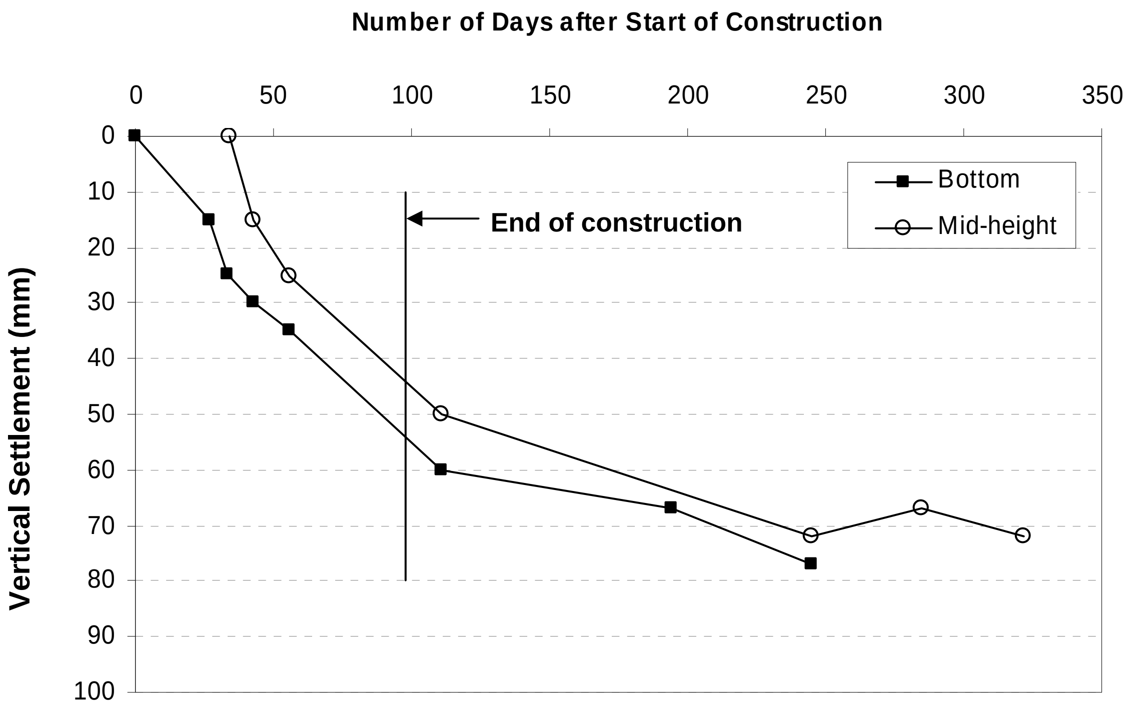

Figure 16 Settlement versus number of days after start of construction (17.7m- Northwest side).

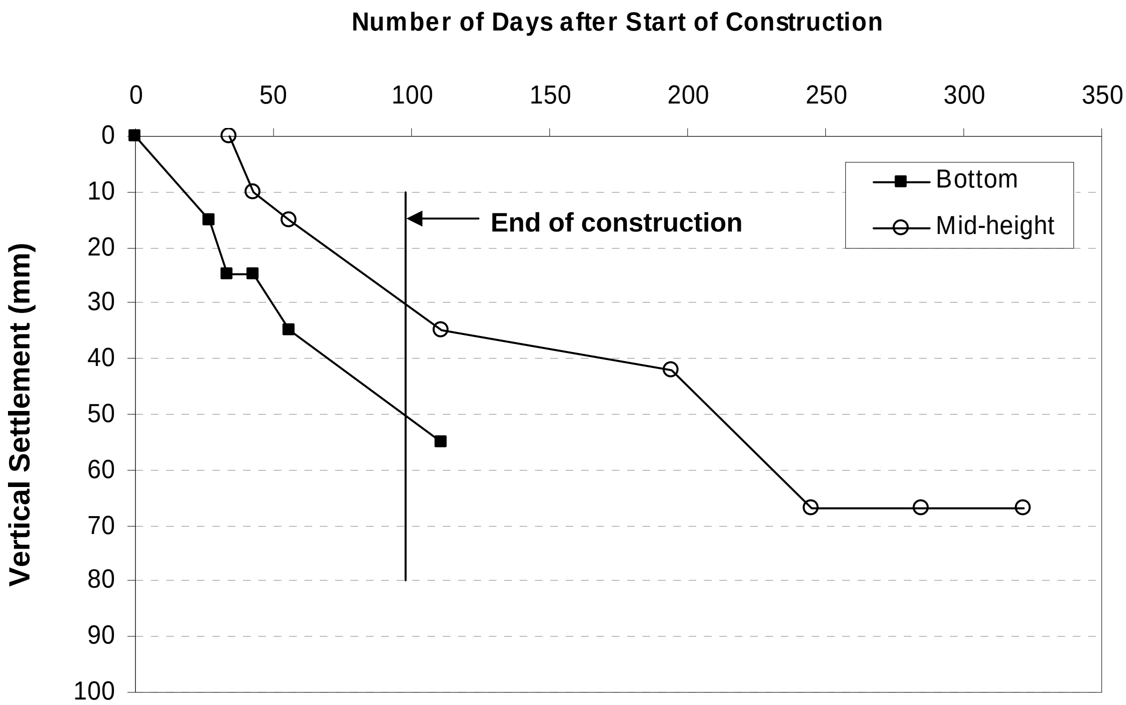

Figure 17 Settlement versus number of days after start of construction (7.8m-Southeast side).

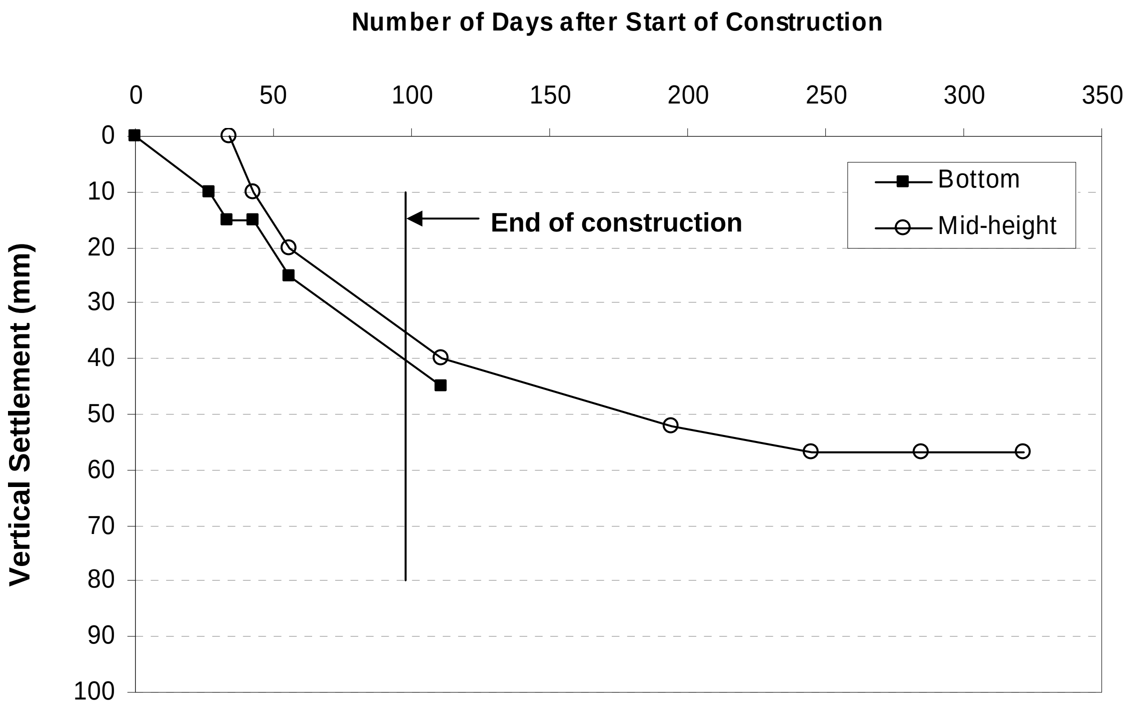

Figure 18 Settlement versus number of days after start of construction (17.7m-Southeast side).

4.2. Piezometers

Piezometric elevations were monitored to meet the design requirements for staged construction, as described in section 3.1. Two piezometers were installed along the section 6 + 250 within the foundation soil. They are located 9 m from the centerline of the embankment on both sides. The piezometric data collected during construction of the embankment are shown in Table 2. The piezometric level was maintained below the critical pore water pressure at all times.

Table 2 Piezometer data collected during construction of the embankment

Days from start of construction	Northwest (Station 6 + 250)			Southwest (Station 6 + 250)		
	Piezometric Head (m)	Fill Height (m)	Critical Piezometric Head (m)	Piezometric Head (m)	Fill Height (m)	Critical Piezometric Head (m)
12	166.840	0.260	170.310	166.565	0.165	169.615
30	167.092	1.697	170.310	166.507	1.567	169.615
50	167.162	2.517	173.470	166.547	2.452	169.615
69	167.402	4.652	173.470	166.642	4.542	172.775

4.3. Horizontal Inclinometers

The horizontal inclinometer monitoring system consists of an inclinometer casing (outer diameter = 70 mm), a portable horizontal inclinometer probe and control cable, and an inclinometer readout unit. The horizontal inclinometer was installed on top of the fly- and bottom-ash embankment along the section 6+270 in order to monitor differential settlement (Figure 5). The monitoring started about three months after the installation date due to inaccessible site conditions. The horizontal inclinometer data are shown in Figure 19. As expected, the maximum differential settlement was observed at the middle of embankment. A maximum differential settlement of 5 mm was observed approximately after five months of monitoring of horizontal inclinometer. These results indicate that the differential settlements in the embankment were minimal.

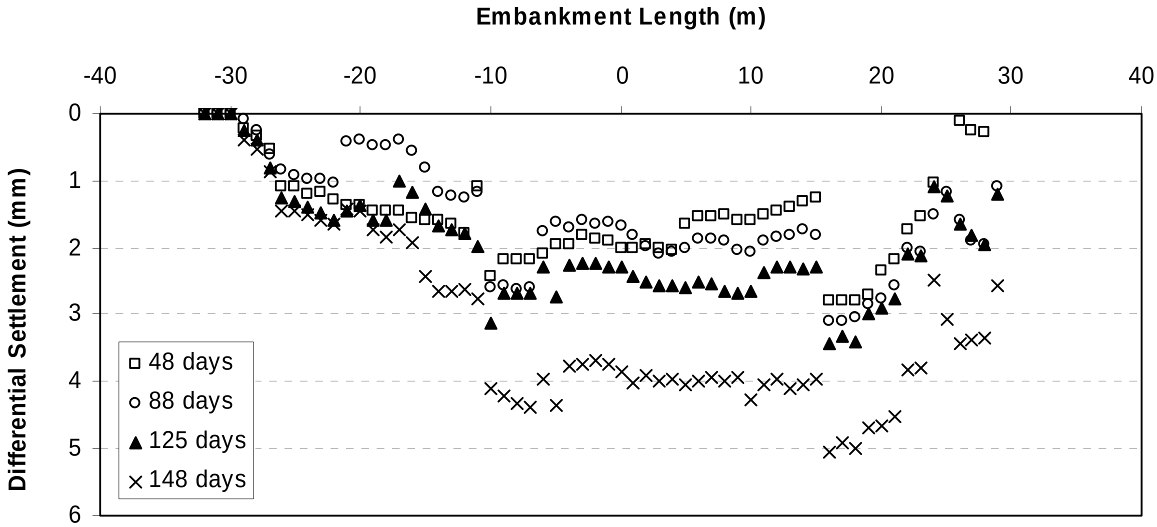

Figure 19 Horizontal inclinometer measurements.

4.4. Vertical Inclinometers

As shown in the layout (Figure 6), two vertical inclinometer casings were installed: one on the shoulder and one on the toe. The vertical inclinometer on the shoulder can detect lateral movement of the slope, and the one on the toe, the movement of the original ground. The vertical inclinometers were installed after completion of the embankment construction. The schematic of the vertical inclinometers installation is shown in Appendix (Figure A.2). Figures 20 and 21 show the lateral movement recorded at the shoulder and toe of embankment. A maximum lateral movement of about 3 mm was observed at the shoulder of the embankment after about four months of monitoring. A lateral movement of less than 1 mm was observed at the toe of the embankment after about four months of monitoring, indicating that there was basically no movement in the foundation soil. The embankment is stable considering the minimal lateral movements recorded.

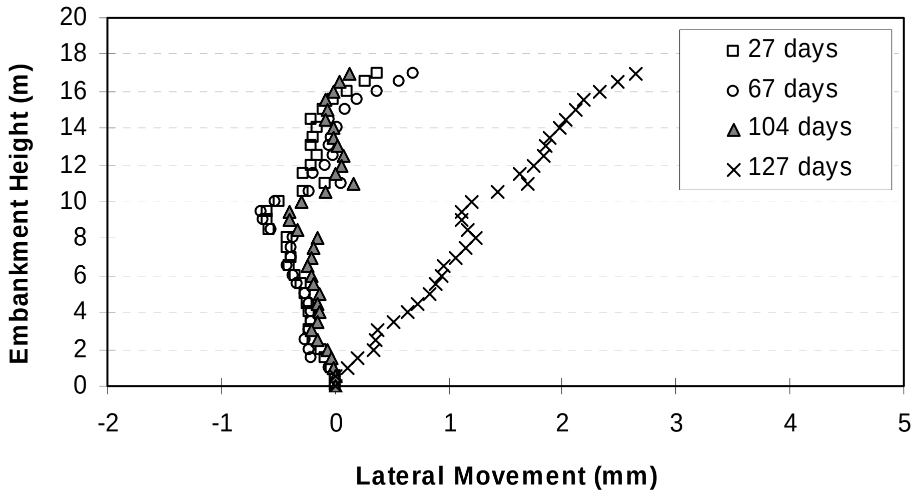

Figure 20 Vertical inclinometer measurements at the shoulder of the embankment.

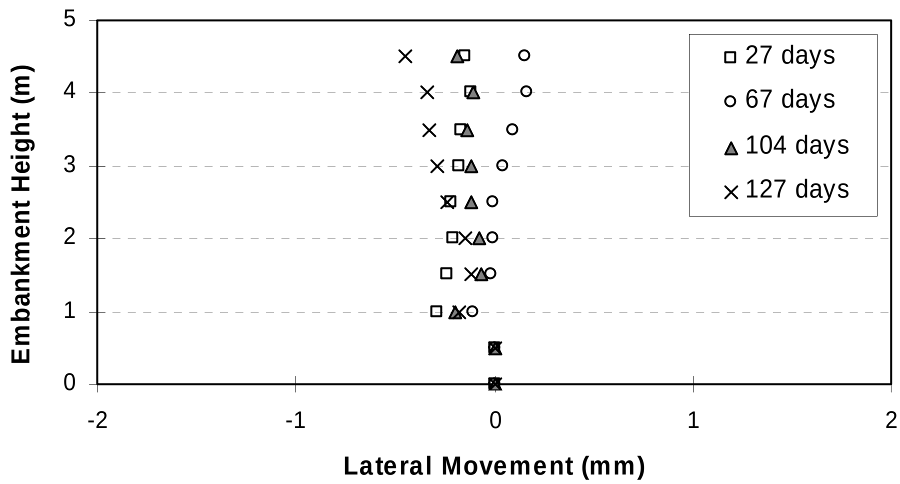

Figure 21 Vertical inclinometer measurements at the toe of the embankment.

CHAPTER 5. SUMMARY AND CONCLUSIONS

The following summarizes the work done and the results of the laboratory testing and field instrumentation program:

(1) A high-volume test embankment using an ash mixture was constructed at State Rd. 641, in Terre Haute, IN. The fill material consists of a mixture of Class F-fly ash and bottom ash (60:40 by mass). The ash mixture was classified as sandy silt according to the USCS. The height, length and width of the test embankment are equal to 7.6 m, 60 m and 100 m, respectively.

(2) The maximum dry unit weight and the optimum moisture content of the ash mixture were found to be equal to 15.1 kN/m^3 and 19 %. It is lighter than the typical fill materials used in highway construction. For this reason, use of ash in embankment construction reduces problems associated with settlement and instability of embankments constructed on top of soft soil deposits. In addition, transportation costs are also reduced because of the reduction in truck load.

(3) Compaction procedures were determined based on test pad results. Nuclear gauge, microwave-oven, and DCPT tests were used for compaction quality control. Based on the test pad results, it was concluded that a DCPT blow count of more than 6 per 150-mm penetration was needed to achieve 95 % of the laboratory $\gamma_{d,max}$.

(4) An empirical correlation between the DCPT blow count and $\gamma_{d,max}$ was proposed based on the data available.

(5) The ash mixture was found to be very uniform. This was quite helpful in achieving uniform compaction of the mixture during construction of the embankment as well. The compaction control was carried out at relatively fewer locations due to the observed fill uniformity. In fact, quality control was relatively easy to accomplish in this project.

(6) The pore pressure developed in each construction stage was maintained below the critical pore pressure measured by the piezometers.

(7) The monitoring program was done for a period of one year after the start of construction of the embankment. The instrumentation program includes settlement plates, and vertical and horizontal inclinometers.

(8) A maximum settlement of 80 mm was observed at the bottom of the embankment; the settlement stabilized approximately three months after the end of construction of the embankment.

(9) Differential settlement of about 5 mm was observed at the top of the ash embankment according to horizontal inclinometer readings obtained approximately after five months of monitoring.

(10) Negligible lateral movements were observed at the shoulder and toe of the embankment; these observations were confirmed by vertical inclinometer readings.

(11) The laboratory and field test results show that the fly- and bottom-ash mixture used in the construction of the demonstration embankment is a viable alternative to conventional fill materials, as it is lightweight and has high strength.

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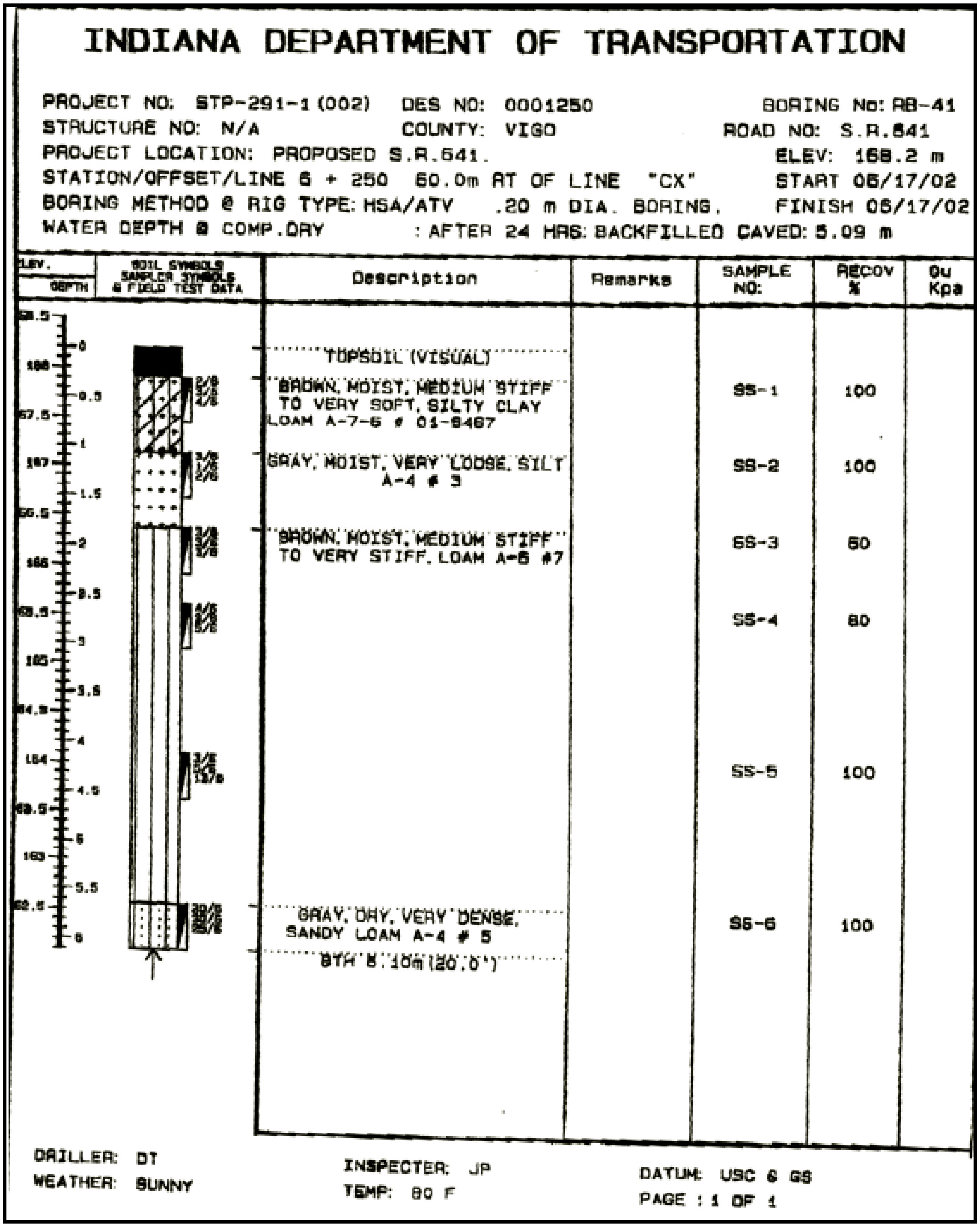
APPENDIX



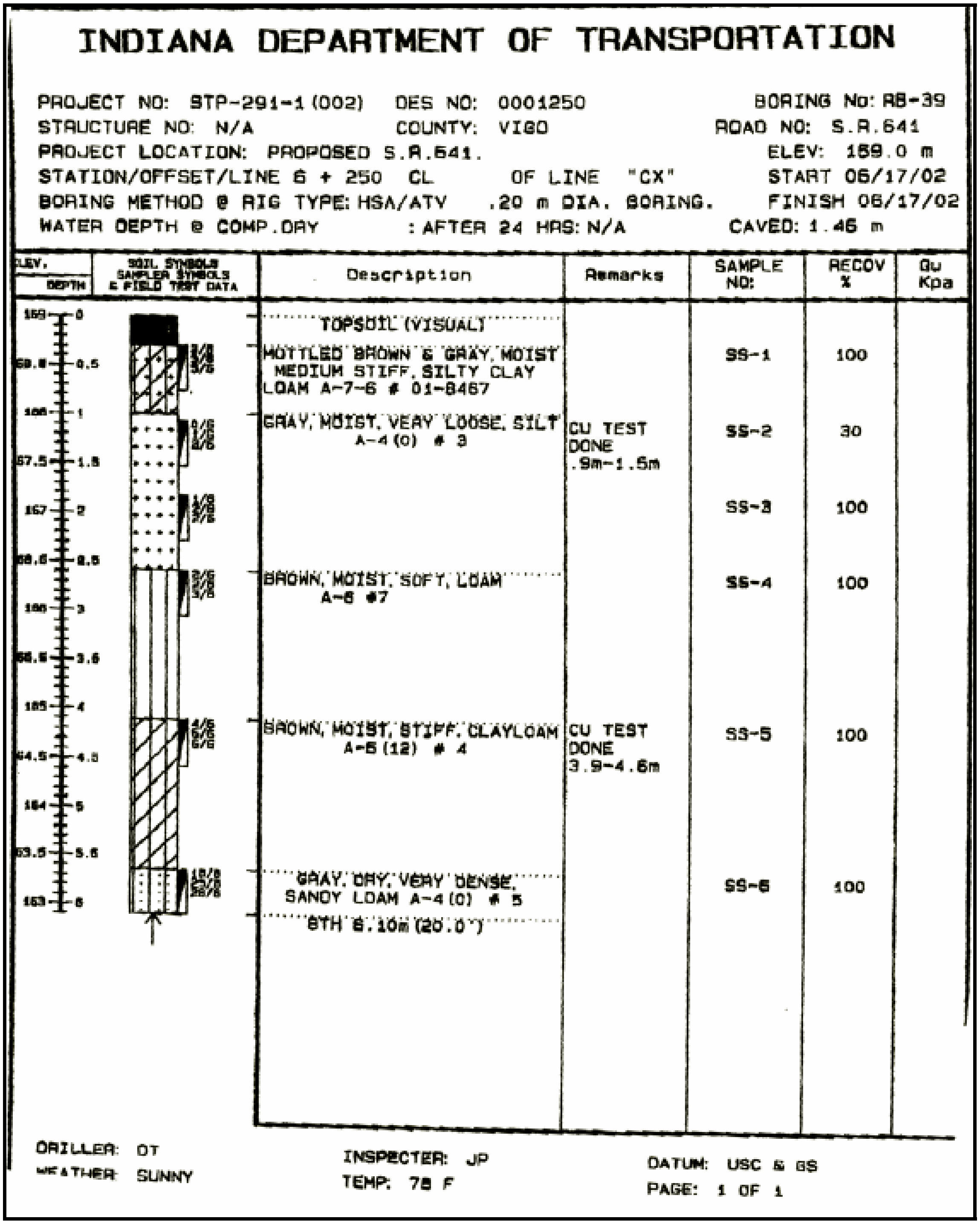
INDIANA DEPARTMENT OF TRANSPORTATION

PROJECT NO: STP-291-1(002) DES NO: 0001250 BORING No: RB-41
STRUCTURE NO: N/A COUNTY: VIGO ROAD NO: S.R.641
PROJECT LOCATION: PROPOSED S.R.641. ELEV: 168.2 m
STATION/OFFSET/LINE 6 + 250 60.0m RT OF LINE "CX" START 06/17/02
BORING METHOD @ RIG TYPE: HSA/ATV .20 m DIA. BORING. FINISH 06/17/02
WATER DEPTH @ COMP.DRY : AFTER 24 HRS: BACKFILLED CAVED: 5.09 m

Description	Remarks	SAMPLE NO:	RECOV %	Qu Kpa
TOPSOIL (VISUAL)				
BROWN, MOIST, MEDIUM STIFF TO VERY SOFT, SILTY CLAY LOAM A-7-6 # 01-8487		SS-1	100	
GRAY, MOIST, VERY LOOSE, SILT A-4 # 3		SS-2	100	
BROWN, MOIST, MEDIUM STIFF TO VERY STIFF, LOAM A-6 #7		SS-3	60	
		SS-4	80	
		SS-5	100	
GRAY, DRY, VERY DENSE, SANDY LOAM A-4 # 5		SS-6	100	
BTH 6.10m (20.0')				

DRILLER: DT INSPECTER: JP DATUM: USC & GS
WEATHER: SUNNY TEMP: 80 F PAGE : 1 OF 1

FIGURE A.1 (a)



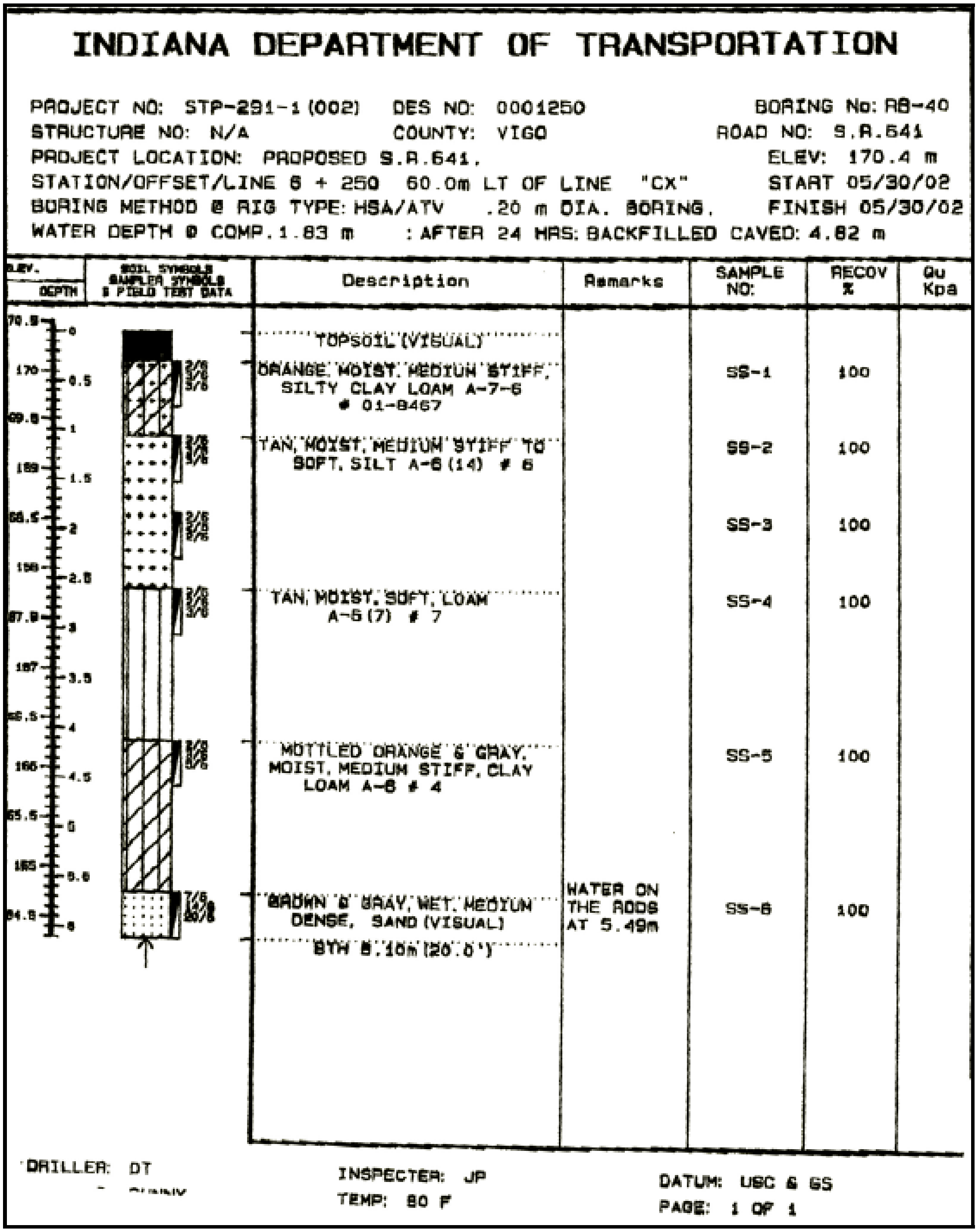
INDIANA DEPARTMENT OF TRANSPORTATION

PROJECT NO: STP-291-1(002) DES NO: 0001250 BORING No: RB-39
STRUCTURE NO: N/A COUNTY: VIGO ROAD NO: S.R.641
PROJECT LOCATION: PROPOSED S.R.641. ELEV: 169.0 m
STATION/OFFSET/LINE 6 + 250 CL OF LINE "CX" START 06/17/02
BORING METHOD @ RIG TYPE: HSA/ATV .20 m DIA. BORING. FINISH 06/17/02
WATER DEPTH @ COMP. DRY : AFTER 24 HRS: N/A CAVED: 1.46 m

ELEV. / DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS & FIELD TEST DATA	Description	Remarks	SAMPLE NO:	RECOV %	Qu Kpa
169 – 0		TOPSOIL (VISUAL)				
0.5		MOTTLED BROWN & GRAY, MOIST MEDIUM STIFF, SILTY CLAY LOAM A-7-6 # 01-8467		SS-1	100	
168 – 1		GRAY, MOIST, VERY LOOSE, SILT A-4 (0) # 3	CU TEST DONE .9m-1.5m	SS-2	30	
167 – 2				SS-3	100	
2.5		BROWN, MOIST, SOFT, LOAM A-6 #7		SS-4	100	
165 – 4		BROWN, MOIST, STIFF, CLAYLOAM A-6 (12) # 4	CU TEST DONE 3.9-4.6m	SS-5	100	
5.5		GRAY, DRY, VERY DENSE, SANDY LOAM A-4 (0) # 5		SS-6	100	
163 – 6		BTH 6.10m (20.0')				

DRILLER: DT
WEATHER: SUNNY
INSPECTER: JP
TEMP: 78 F
DATUM: USC & GS
PAGE: 1 OF 1

FIGURE A.1 (b)



INDIANA DEPARTMENT OF TRANSPORTATION

PROJECT NO: STP-291-1(002) DES NO: 0001250 BORING No: RB-40
STRUCTURE NO: N/A COUNTY: VIGO ROAD NO: S.R.641
PROJECT LOCATION: PROPOSED S.R.641. ELEV: 170.4 m
STATION/OFFSET/LINE 6 + 250 60.0m LT OF LINE "CX" START 05/30/02
BORING METHOD @ RIG TYPE: HSA/ATV .20 m DIA. BORING. FINISH 05/30/02
WATER DEPTH @ COMP. 1.83 m : AFTER 24 HRS: BACKFILLED CAVED: 4.82 m

ELEV. / DEPTH	SOIL SYMBOLS SAMPLER SYMBOLS & FIELD TEST DATA	Description	Remarks	SAMPLE NO:	RECOV %	Qu Kpa
		TOPSOIL (VISUAL)				
		ORANGE, MOIST, MEDIUM STIFF, SILTY CLAY LOAM A-7-6 # 01-8467		SS-1	100	
		TAN, MOIST, MEDIUM STIFF TO SOFT, SILT A-6 (14) # 6		SS-2	100	
				SS-3	100	
		TAN, MOIST, SOFT, LOAM A-6 (7) # 7		SS-4	100	
		MOTTLED ORANGE & GRAY, MOIST, MEDIUM STIFF, CLAY LOAM A-6 # 4		SS-5	100	
		BROWN & GRAY, WET, MEDIUM DENSE, SAND (VISUAL)	WATER ON THE RODS AT 5.49m	SS-6	100	
		BTH 6.10m (20.0')				

DRILLER: DT
INSPECTER: JP
TEMP: 80 F
DATUM: USC & GS
PAGE: 1 OF 1

FIGURE A.1 (c)

FIGURE A.1 (a), (b), (c) Boring logs conducted at the CL of embankment (6+250).

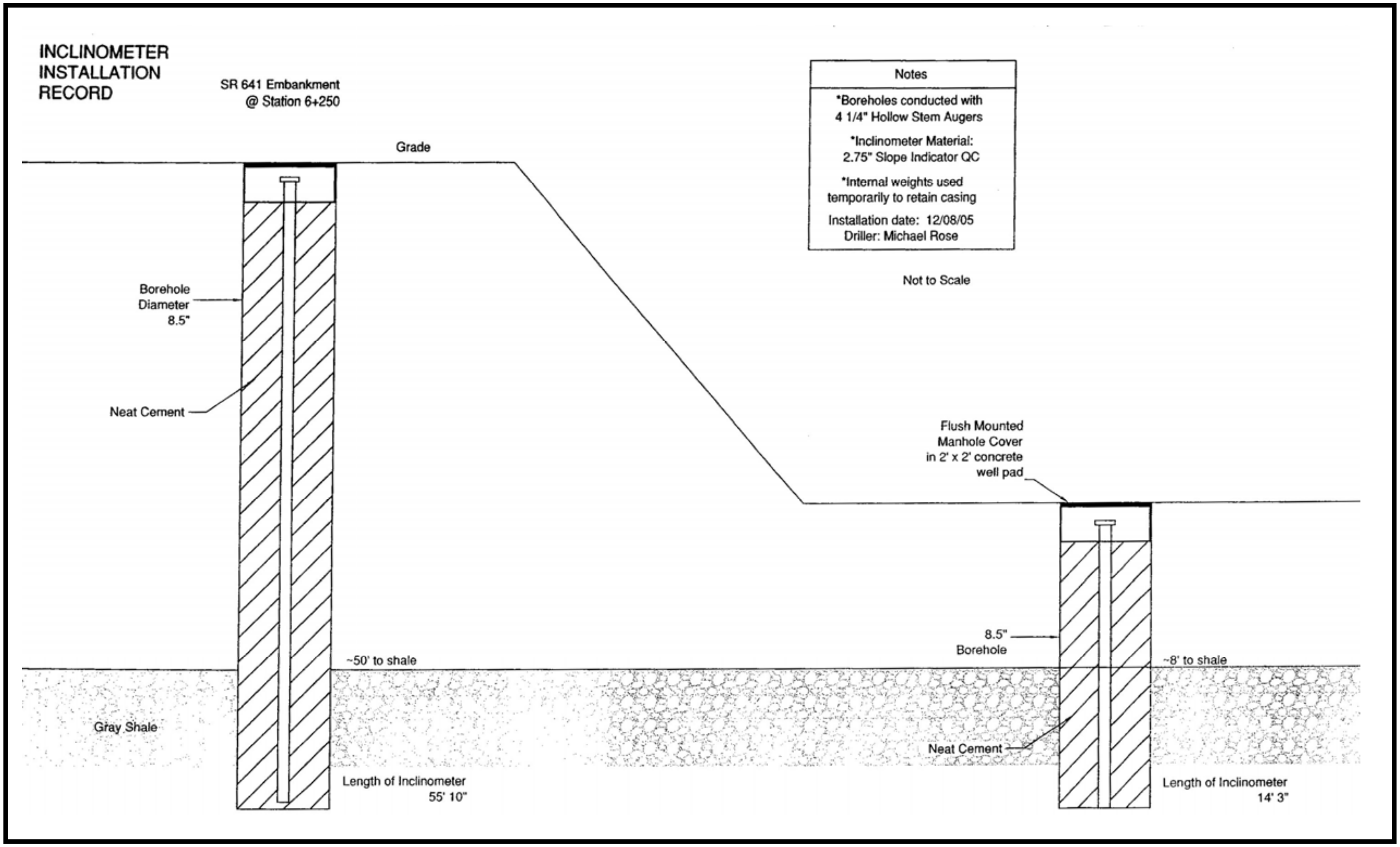


Figure A.2 Vertical inclinometers installation.